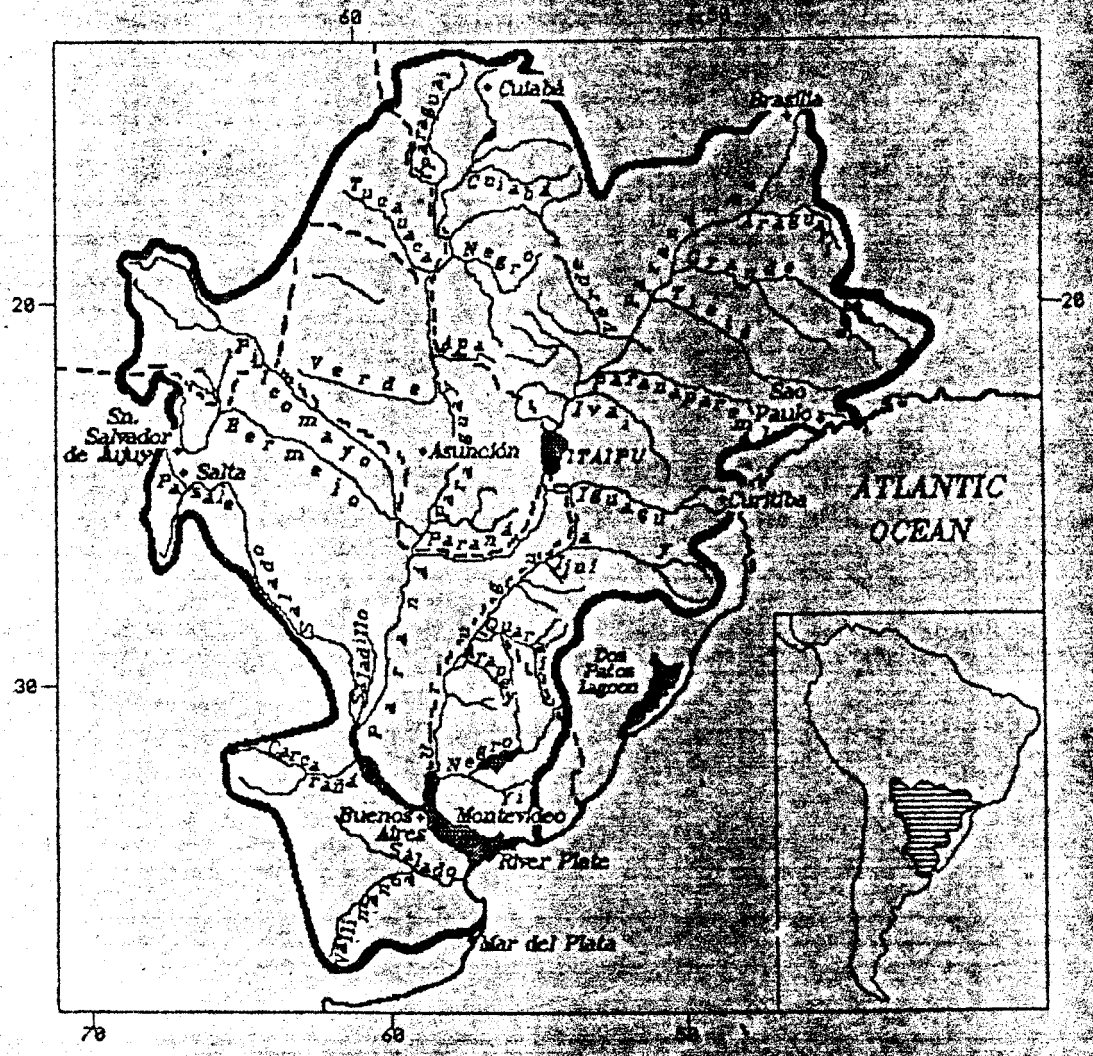
Environmental and Social Dimensions of Reservoir Development and Management in the La Plata River Basin



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ITAIPU RESERVOIR: IMPACTS ON THE ICHTHYOFAUNA AND BIOLOGICAL BASES FOR ITS MANAGEMENT

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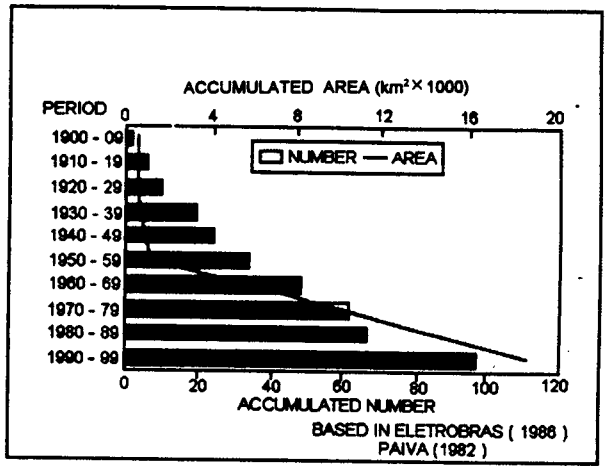
INTRODUCTION

Impoundments are the main source of human interference of Brazil's continental waters. Initially built to supply water for domestic and agricultural use, dams have increasingly become important for their ability to generate electricity. Improvements in excavating technology has led to a great increase in dam sizes and has enabled large rivers to be impounded. Hydroelectric reservoirs in eastern Brazil are changing the main water courses in the south, southeast and eastern regions, impounding large areas in the basins and interfering with the natural regime of floods in areas not yet inundated.

The hydrological and limnological regime of the Brazilian section of the Paraná River has been considerably altered in the past decades. In this case, the increase in number and scale of impoundments, intensification of agriculture, industries, and large cities, have all contributed to this process. At the beginning of the 1960s, the total dammed area was about 1,000 km^2. By the end of this century, considering only the larger reservoirs, this area will be close to 20,000 km^2 (figure 11.1). The larger tributaries of the Paraná River, like the Grande, Tietê, Paranapanema and Iguaçu rivers have been greatly changed by hydroelectric reservoirs. The Paraná River, which extends about 800 km into Brazilian territory,[1] has only about 500 km left free and half of that will be modified by the Porto Primavera reservoir (*Centrais Energéticas de São Paulo*), to be completed in 1995. The Ilha Grande Hydroelectric project (ELETROSUL), whose construction has been suspended, would eliminate the last lotic reach of this river upstream from the Itaipu reservoir.

The diversity of fish in the Paraná River Basin is among the greatest in the world. The area, which has sustained a promising fishery industry, has unfortunately been subjected to increasing alteration of its habitat. Some species have disappeared from the basin's higher reaches and are now only in relatively undisturbed areas such as in the 300 km upstream from Itaipu reservoir. The growth of human communities in this region also poses a grave threat on the fish. For ethical and social reasons, the hydroelectric operators, the government and research institutions, should implement effective managerial action to assure the survival of those fish. In context, this paper intends to discuss some of the fish fauna alterations since the construction of the Itaipu reservoir. It will also look at the region's commercial fisheries and biological information on the main species caught by those fisheries.

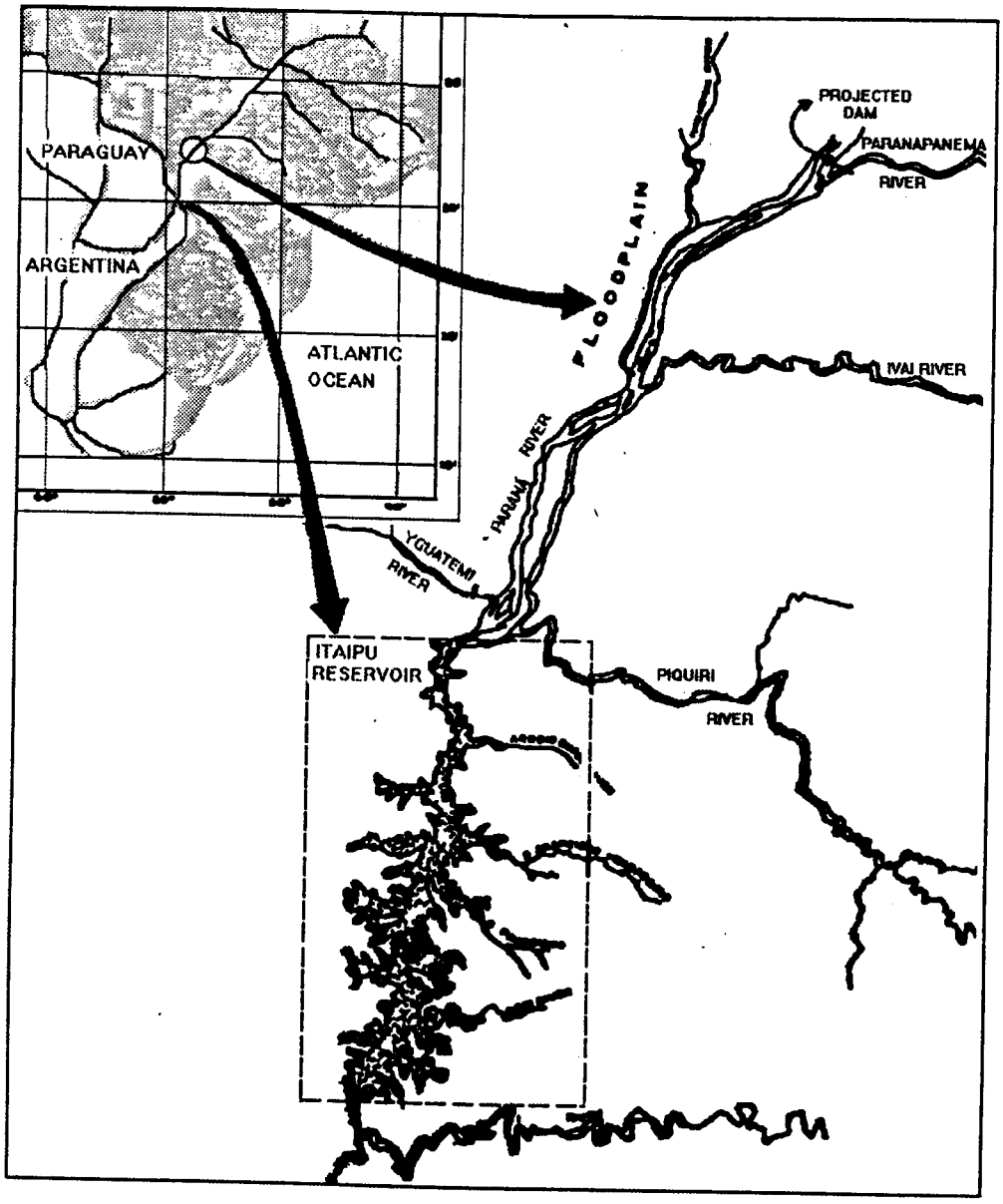
Figure 11.1. Evolution of the Number and Area of Reservoires in Paraná Basin



CHARACTERISTICS OF THE ITAIPU RESERVOIR

The gates of the Itaipu reservoir were closed officially in October 1982. It encompasses an area of 1,460 km^2 when as its maximum quota and is about 150 km in length. Its average depth is 21.5 m, with a maximum of 170 m. The duration of water residence is about forty days. The mean water velocity measured on the surface of the central body is 0.6 m/s.

Figure 11.2. Itaipu Reservoir



The region of the Paraná River which is now flooded, previously ran along a narrow canyon without floodplains. It commenced at the Sete Quedas falls (Guaíra). There is a large floodplain on the river's left side upstream from the Itaipu reservoir.[2/]

Studies by the *Superintendência de Recursos Hídricos e Meio Ambiente do Estado do Paraná* show that the central body of the Itaipu reservoir has an annual cycle of thermal stratification in the spring and summer. The metalymnion ranges from 15 m depth down to the bottom and the stratification of this reservoir is attributed to hydraulic conditions and the annual temperture ranges in the Paraná River.[3/]

Metalymnion and hypolymnion stratifications have low oxygen concentrations and anoxia may sometimes occur in restricted areas.[4/] Its trophic state, based on total phosphorus and chlorophyll, an annual variation combined in the Carlson Index, is considered to be mesotrophic with eutrophic tendencies in some branches during certain times of the year.[5/]

Factors limiting primary production are the low phosphorus levels in winter and spring (<.01 mg/l), the high abiotic turbidity in summer, and the low euphotic zone/maximum depth relationship that characterizes it.[6/] The on-site studies reveal a reduction in turbidity, nutrient concentrations, phytoplankton and other trophic

level organisms.[7] The residual level of heavy metals and agrochemicals in the water and fish tissues are considered to be low.[8]

Impacts Upon Fish Resulting from the Impoundment

More than 110 fish species were found upstream from the Sete Quedas falls in the Paraná River between 1978 and 1981.[9] In the years following the impoundment, however, only 83 species were caught in the flooded area. In fact, six small fish species *Otocinclus vittatus, Xenurobrycon macropus, Roeboides prognatus, Cochliodon cochliodon, Bryconamericus iheringii, and Oligosarcus jenynsii*) were not found in any experimental fishing in the area. These fish had previously appeared sporadically. Other species not registered in the reservoir were caught downstream or in tributaries.[10]

Some large species, such as the pacu (*Piaractus mesopotamicus*) and the piracanjuba (*Brycon orbignyanus*, previously common downstream from the dam, apparently disappeared from the region within a few years of the impoundment. The species basically lived on fruit matter washed downstream. They were therefore seriously affected by the low marginal area/water lamina relationship.

Conversely, migratory species, such as *Leporinus elongatus, Leporinus obtusidens, Prochilodus scrofa, Pseudoplatystoma corruscans*, that would normally leave the impounded area, have remained and constitute a large part of the local fish production. These species use the floodplain of the Paraná River upstream from the Itaipu reservoir during one phase of their life cycle. *Salminus maxillosus*, the largest Characiformes in the basin, only appears sporadically in the reservoir fisheries, although young specimens are abundant during the months when the floodplain is full. Similar conditions apply to other reophylic species, specially during years of high floods. This phenomenon may be related to the retraction of flooded areas and the consequent high density of young in the channel and dispersion for other points of the basin.

The impoundment has drastically changed fish populations. For example, nine of the ten most common fish in the experimental fishery prior to the impoundment have since lost their placing. The exception being *Plagioscion squamosissimus* (figure 11.3). It is worth noting that this species was introduced to the upper regions of the basin in 1967.[11]

One species that has proliferated after the impoundment is the mapará (*Hypophthalmus edentatus*); the only known plankton-eater in the higher Paraná River. The fish, one of the three most numerous species caught by commercial fisheries in the reservoir, has a short life-span,[12] and high fertility and can spawn twice a year.[13] These factors combined with plentiful food and absence of food rivals, has enabled the fish to proliferate.

Another successful species is the insectivore, surumanha (*Auchenipterus nuchalis*). Like the mapará, it has a short life and matures quickly. It also has internal fecundation, a reproductive feature that it shares with two of the other five most common fish in the reservoir.

The impoundment triggered a decline in the previously abundant mud-feeding species. These species had comprised 57 per cent of fish caught in the region prior to the damming.[14] These figures ranged between 8.6 per cent and 19.7 per cent in the first six years after the impoundment.[15] The insectivores, conversely, proliferated, alternating with the piscivorous species as the predominant group. The carnivores maintained their levels, but there was considerable annual variation regarding feeding habits (figure 11.4). It would therefore seem that six years after impoundment, the fish communities were already into the installation phase. The upstream floodplain seems to have influenced this colonization by exerting a direct effect on the replenishment of stocks in the reservoir.

Fishery

Fish production tends to initially rise after a reservoir has been built before falling and stabilizing. Importantly, however, the fish yield normally remains higher than before the river was impounded. This fact basically reflects the environment's trophic state. The time required for fish stocks to stabilize and the eventual production level depend on many factors. The morphometry of the catchment basin, its flow, standard circulation, depth, area, location, together with the dam design and operational procedures, are some variables.[16] The flood regimes in the upstream

Figure 11.3. Relative Frequency of the Ten Principal Species Before and After Itaipu Impoundment

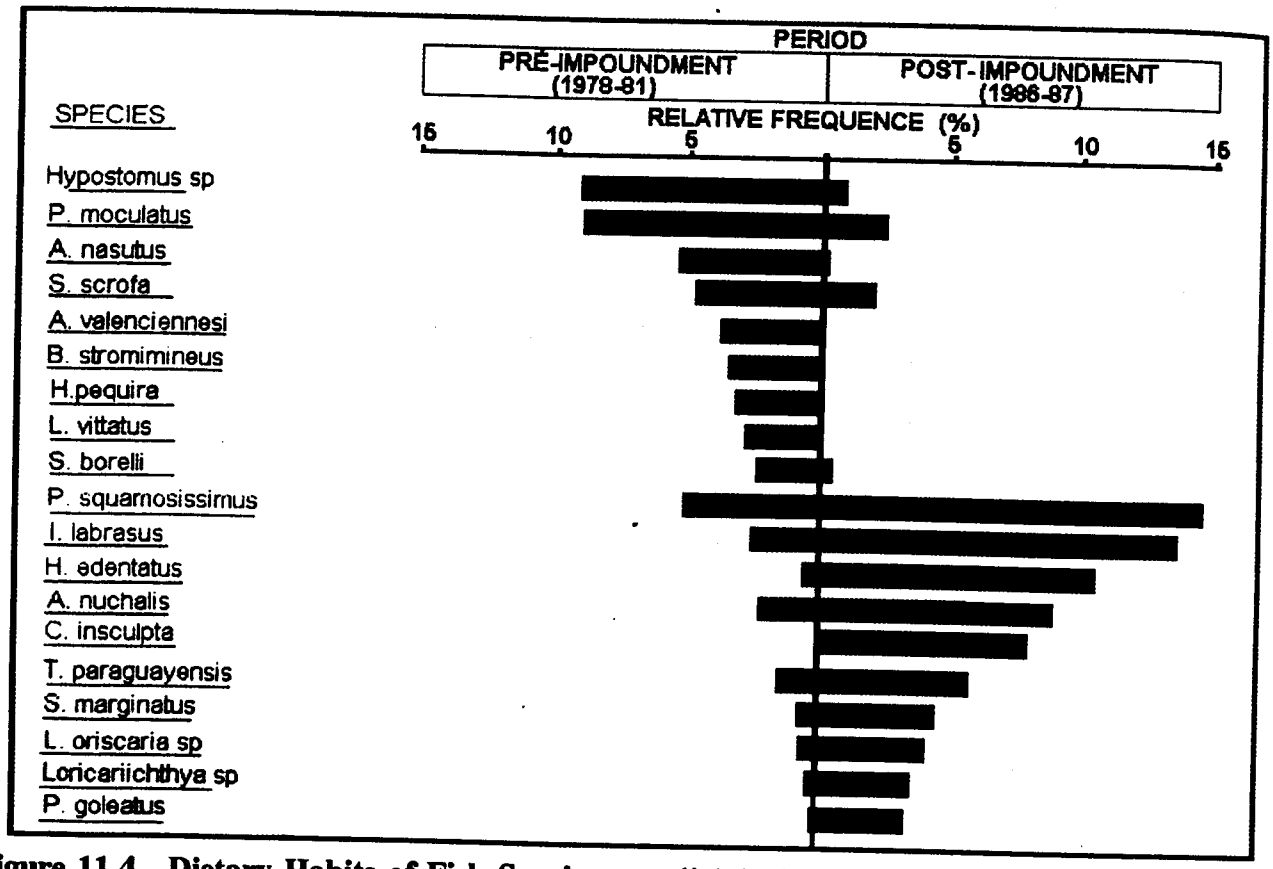
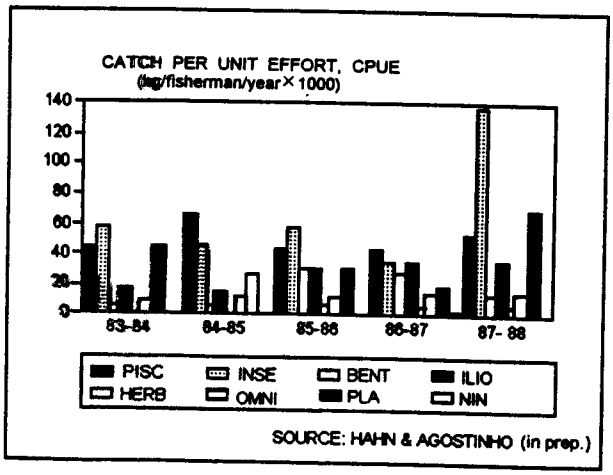


Figure 11.4. Dietary Habits of Fish Species



floodplains are another influence for the Itaipu reservoir.

Almost a thousand fishermen work at the Itaipu reservoir. They mainly fish in the upper half of the reservoir and most use gillnets. The monitoring of the fishery that commenced in 1985, has revealed an annual catch between 1.42 and 1.77 thousand tons. Yields for fishermen with their own boats and fishing materials increased between 1985 to 1989, however, fell slightly in 1990 (figure 11.5). This decrease is probably due to a decline in fishing that year brought about by new fishing regulations.

Although there are more than 50 species in the fishery reservoir, nine species account for nearly 90 per cent of the catch (table 11.1). It is worth noting that Siluriformes and Characiformes were a major part of the catch in the experimental fishery, yet only one species of Characiformes (*Prochilodus scrofa*) was the commercial fishery's nine major species. Siluriformes, on the other hand, were represented by seven species.

The variation analysis of annual catches between 1987 and 1990 (figure 11.6) shows a decrease in curimba (*Prochilodus scrofa*), barbado (*P. pirinampu*), pintado (*P. corruscans*) and an increase in armado (*P. granulosus*) and mapará (*H. edentatus*). Other species remained stable.

Five species in the commercial fishery account for about 75 per cent of the catch. *H. edentatus* and *P. granulosus* are more abundant in the Santa Helena region, which comprises about half the reservoir. *P. granulosus* is caught mainly in the upper third and *R. aspera* in the Guaíra

Table 11.1. Relative Abundance and Occurrence of the Five Principal Species in the Itaipu Reservoir Fishery

Area/species	*P. scrofa*	*H. edentanus*	*P.squamosissimus*	*P.granulosus*	*R.aspera*
Guaíra	++	+	+++	+++	++++
Pato Bragado	++	+++	++++	++	+
Sta. Helena	++++	++++	++++	+	+
S. Miguel	+	++	++	+	.
Foz Iguaçu	++	++	+	+	.

.= absent, + = esporadic, ++ = frequent, +++ = abundant, ++++ = very abundant

Figure 11.5. Catches in the Itaipu Reservoir, 1987–1990

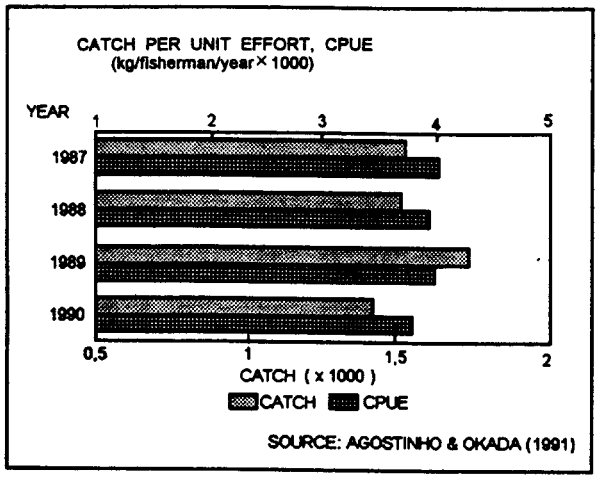
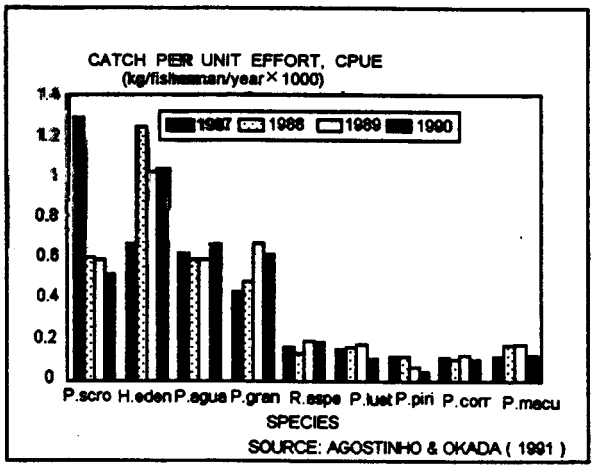


Figure 11.6. Catches of the Principal Fish Species in the Itaipu Reservoir, 1987–1990



region. *P. squamosissimus* lives in the upper half of the reservoir.

The fact that fish population has slightly risen, not fallen, in the reservoir is probably due to a large floodplain that acts as a natural breeding preserve for some fish species and which supports the fishery in the impounded area. This has been shown in studies carried out by the *Universidade Estadual de Maringá*. Thus, fish production in the Itaipu reservoir is expected to increase or continue at the same level, since the management measures being taken should be extended to other parts of the basin.

BIOLOGICAL BASES FOR FISHERY MANAGEMENT

Research at the Itaipu reservoir and its basin upstream was started in November 1983 by the *Universidade Estadual de Marigá – Núcleo de Pesquisas em Limnologia, Ictiologia e Aquicultura* (NUPELIA) and Itaipu Binacional. These efforts have produced a fund of biological knowledge that along with socio–economic data can provide alternative management schemes for fisheries.

Details include the following:

The reproductive behaviour of ninety–three fish species were evaluated in thirteen localities of the Paraná River Basin. The areas were the Itaipu reservoir (Guaíra, Santa Helena, Foz do Iguaçu), its tributaries (Arroio Guaçu, São Francisco, Verdadeiro, São Francisco Falso and Ocoí), the Paraná River, its tributaries (Piquiri, Iguatemi and Ivinheima rivers) and floodplain (marginal lagoons and channels) (table 11.3).

Among these localities, the largest number of species was in the Piquirí River, followed by the Iguatemí. These rivers flow into the Paraná River a few kilometers from the Itaipu reservoir and have different physiographical characteristics. The most notable feature is that the water is typically torrential. The migratory fishes enter from other points of the basin during the reproductive period. Among the reservoir

Table 11.2. Species in Reproduction Frequency by Sample Station

Localities	N	n	%
Guaíra	62	11	17.7
Sta. Helena	56	17	30.4
Foz Iguaçu	47	08	17.0
A. Guaçu	40	12	30.0
S. Fco Falso	36	13	36.1
S. Fco Verdadeiro	35	07	20.0
Ocoí	36	11	30.6
Piquiri	37	19	51.4
Iguatemi	35	14	40.0
Ivinheima	45	09	20.0
Paraná	42	11	26.2
Marginal channels	49	11	22.4
Marginal lagoons	44	14	31.8

N = species number, n = number in intense reproductive activity

Table 11.3. Monthly Frequency of Species in Reproduction

Month	N	n	%
January	68	34	50.0
February	61	24	39.3
March	49	02	4.1
April	54	02	3.7
May	38	00	00.0
June	43	01	2.3
July	45	00	00.0
August	45	02	4.4
September	50	08	16.0
October	60	42	70.0
November	64	44	68.8
December	64	43	67.2

N=species number, n=number in intense reproductive activity

stations, only Santa Helena had many species undergoing intense reproductive activity, a fact that can be attributed to its closeness to important tributaries, specially on the right side. The tributaries on the left contain many of the species that are reproducing and, together with the lagoons and channels on the floodplain of the Paraná River upstream, are vital for the initial phases of development.[17]

For most species, reproductive activity was most intense from October to February (table 11.3), particularly during the first three months.

Information regarding the five major species in the reservoir fishery production (75 per cent of the biomass landed) obtained from experimental fishery and commercial fishery samples are summarized as follows:

(1) Maturity and Length

Figure 11.7 shows the length at first sexual maturity as well as the amplitude between total lengths of the landed fish production. There is a large variation in lengths; which makes it difficult to establish an adequate mesh size for the fishery.

It should be noted that catches of young *Pterodoras granulosus* occur almost entirely in the branches of the reservoir near the tributaries, however, most fishermen set them free.[18]

Weight Length Ratios – The values of the parameters (a and b), of the Pearson correlation (r) of the equation that relates weight to total length, can be applied to fishery monitoring and the number of fish used in the estimates are shown in Table 11.4.

Figure 11.7. Range Length at First Maturity (L50%) and L100% of the Five Principal Species in the Itaipu Fishery

VAZZOLER et al. (in prep.)

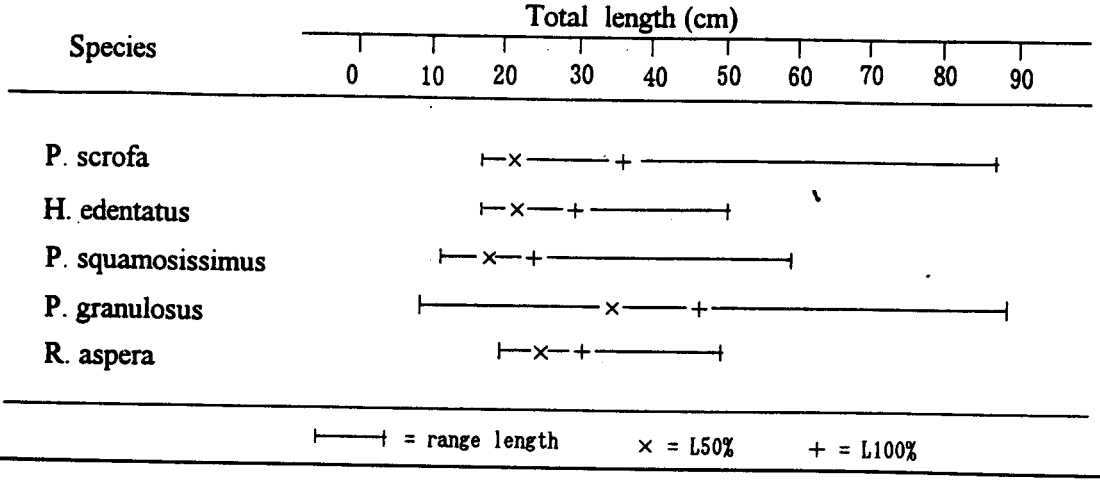


Table 11.4. Weight/Length Parameters of the Five Principal Species in the Itaipu Reservoir Fishery

Species	n	a	r	r
P.scrofa	4090	0.0197	3.087	0,97
H.edentatus	843	0.0112	2.969	0,96
P.squamosissimus	6915	0.0164	3.076	0,98
P.granulosus	1557	0.0364	2.883	0,98
R.aspera	1321	0.0151	3.002	0,98

n=number, a,c,b=regression coefficients, r=correlation coefficient

Table 11.5. Alimentary Spectrum of the Five Principal Species in the Itaipu Reservoir Fishery

Food/Species	*H.edentatus*	*P.squamo-sissimus*	*P.scrofa*	*P.granu-losus*	*R.aspera*
Testacca	–	–	–	++	–
Rotifera	–	–	–	++	–
Bryozoa	–	–	–	++	–
Microcrustaceans	+++++	–	–	++++	–
Decapoda	–	+	–	–	–
Mollusca	–	–	–	++	–
Arachnida	++	–	–	++	–
Insects	+++	+++	–	+++	–
Fish	–	+++++	–	–	–
Algae	+++++	–	+++++	+++	++++
Plants	–	+	++++	++++	+++
Sediment	–	–	+++++	+++	+++++
Predominant habit	plankto-phagous	carnivorous	mud-feeder	omni-vorous	mud-feeder
Source	LANSAC-TOHA et al.(1991)	HAHN (1991)	*	*	*

* FUEM-Itaipu Binancional, 1990
– = absent, + = sporadic, ++ = frequent, +++ = very frequent, ++++ = abundant, +++++ = very abundant

Table 11.6. Growth Curve Parameters of Three Principal Species in the Itaipu Reservoir Fishery

Species	L_o	k	t_o	Source
P. squamosissimus	86.2	0.086	-2.36	HAYASHI et al.(in prep.)
P. scrofa	68.2	0.157	-0.85	HAYASHI et al.(in prep)–
R. aspera	68.2	0.116	0.84	AGOSTINHO et al.,1991

L_o = asymptotic length, k = intrinsic growth rate, t_o = age at zero length

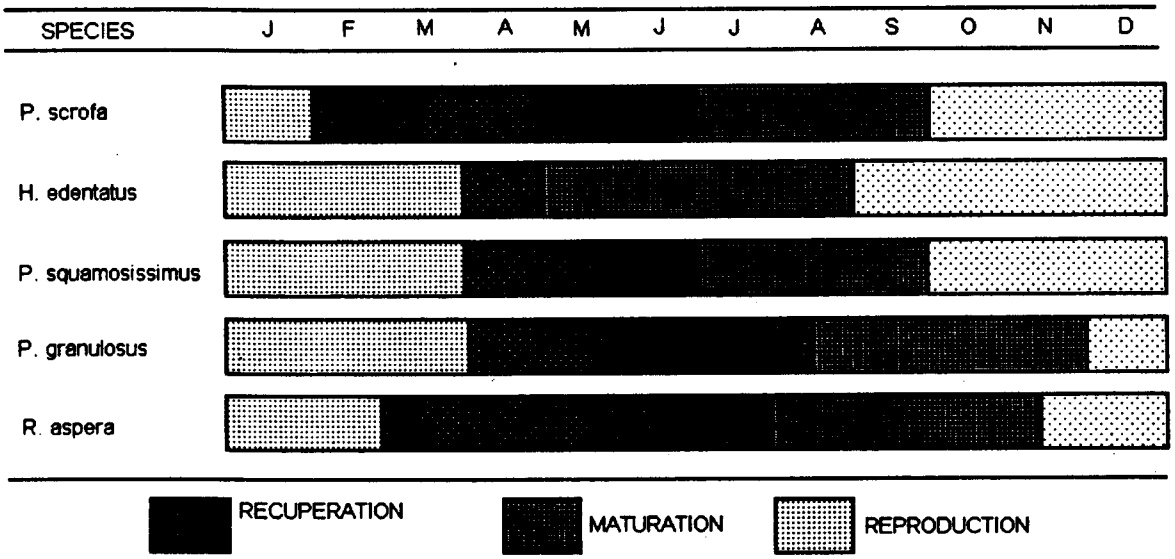
Feeding: Among the five principal species of the Itaipu reservoir, two are mud-feeders, one planktophagous, another carnivorous and the other omnivorous. Table 11.5 shows the main items these fish ate. The diet of the plankton eating *Hypophthalmus edentatus* consists mainly of Cladocera (*Bosmina hagmani*) and Cyanophyceae (*Microcistis* spp).[19]

Table 11.7. Gonadosomatic Relation Values of the Five Principal Species in the Itaipu Reservoir Fishery

Species/stage		Recuperation	Maturation	Reproduction	Spent	GSR_{max}
P.scrofa	avg sd	0.50 0.001	3.02 0.254	9.68 0.592	0.69 0.046	20.11
H.edentatus	avg sd	0.42 0.005	0.80 0.029	3.14 0.057	0.69 0.016	9.82
P.squamosissimus	avg sd	0.13 0.001	0.74 0.061	1.19 0.058	0.18 0.016	3.34
P.granulosus	avg sd	0.51 0.006	1.01 0.188	2.95 0.227	0.68 0.051	7.81
R.aspera	avg sd	0.28 0.008	1.72 0.418	5.92 0.566	1.71 0.111	13.1

GSR= gonadosomatic relation, avg=average, sd=standard deviation

Figure 11.8. Reproductive Intensity of the Five Principal Species in the Itaipu Reservoir Fishery by Sample Station



Plagioscion squamosissimus feeds on 56 species of fish, with *H. edentatus* and *Roeboides paranensis* forming the basis of its food in the reservoir. *Prochilodus scrofa* and *Rhinelepis aspera* feed on organic sediments and periphyton. The submerged arboreal vegetation on the right side which was flooded during the impoundment supplied a large substratum for periphyton development, a fact that principally favoured curimba (*P. scrofa*). The expected reduction of this resource should reduce the stock of the species. *Pterodoras granulosus*' is principally herbivorous, however, it occasionally feeds on items of allochthonous and autochthonous origin.[20] It also has the largest diversity in alimentary composition; this adaptability is an important reason for its increasing population density in the Itaipu reservoir.

Age and Growth: Table 11.6 shows the growth curve of three of the five most important species. The von Bertalanffy equation parametres, which are a handy tool to evaluate stocks and estimate the maximum sustainable yields, are shown in table 11.6.

Gonadosomatic Ratio: The mean values of the gonadosomatic ratio (GSR) for each species and the ovarian maturity stages applied to quantify gonadal development, are presented in

Table 11.8. Reproductive Intensity of the Five Principal Species in the Itaipu Reservoir Fishery by Sample Station

Locality/species	*P.scrofa*	*H.edentatus*	*P.squamosissimus*	*P.granulosus*	*R.aspera*
Guaíra	–	+	–	+++	+++
Sta.Helena	–	+++	–	–	–
Foz Iguacu	–	+	++	–	–
A.Guacu	–	–	++	–	
S.Fco.Falso	–	–	++	–	
S.Fco.Verdadeiro	–	–	+++	–	
Ocoi		–	+++	–	
Piquiri	+++				
Iguatemi	+++	–	–	+	–
Ivinheima	–	–	–	+	+++
Paraná	++	–	–	++	+++
Marginal lagoons	–	++	–		
Marginal channels	–	–	–	–	

table 11.7. It also shows their standard deviation and the maximum values of the GSR during the period. This data is useful for the evaluation of the species' reproductive activity.

Reproductive Cycle: The timing of reproductive cycle for the five species is shown in figure 11.8. Studies undertaken over six years, show that reproduction occurs mainly from September to March. *H. edentatus* is the first to begin and *P. Granulosus* the last. The reproductive period for *H. edentatus* and *P. Squamosissimus*, extend for seven and six months respectively, but only three or four months for other species.

Reproductive Activity and Locality: The reproductive intensity for each species in 13 localities is shown in table 11.8. The mapará (*Hypophthalmus edentatus*) is the only species whose reproduction was restricted to lentic environments (Itaipu reservoir and marginal lagoons upstream). *Plagioscion squamosissimus* had moderate reproductive activity in the reservoir and spawns in the tributaries.

The armado (*P. Granulosus*) reproduced in lotic environments (e.g., Paraná and Iguatemí rivers) and in the transition region between the Paraná River and the reservoir. This species had been introduced into the river section above Guaíra after the Sete Quedas falls had been submerged by the Itaipu reservoir. The spawning area of the cascudo-preto (*R. Aspera*) is the same as for the armado, with the exception of the Iguatemi River. The curiba (*P. Scrofa*) also only reproduces in lotic environments, migrating upwards to the Paraná, Piquiri and Iguatemi rivers for spawning.[21]

Larval Distribution: Many eggs and larvae were found for mapará and curvina. Table 11.9 shows the monthly larval abundance of these species.[22] For both species there is obviously nearly an overlap between the period of larval occurrence and the spawning.

The analysis of larval abundance of these two species, taking the sampling localities into consideration (table 11.10), reveals a large distribution for both species, with the mapará (*H. Edentatus*) concentrated in the intermediate regions and the curvina (*P. Squamosissimus*) in the internal areas. The largest concentrations of these species' larvae occur in the discharges of tributaries.[23]

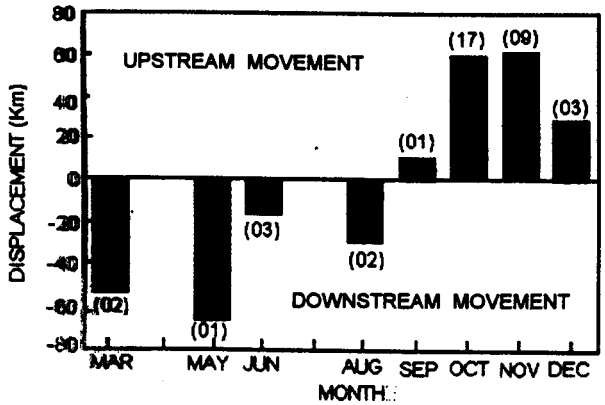
Migratory Movement: Tagging and recapture studies have been carried out in the

Table 11.9. Relative Abundance of *H. Edentatus and P. Squamosissimusl* Larvae in the Itaipu Reservoir by Month

Month/Species	*H.edentatus*	*P.squamosissimus*
January	++++	++++
February	++++	++++
March	++++	+++
April	+	++++
May	–	–
June	–	–
July	–	–
August	–	–
September	–	–
October	+	+
November	++++	++
December	++++	+++

–: absent, +: sporadic, ++: frequent, ++++: abundant, ++++: very abundant

Figure 11.9. Movements of *P. Scrofa* in the Itaipu Reservoir and Paraná River



SOURCE: AGOSTINHO ET AL (IN PRESS)

Itaipu reservoir region and the upstream stretch of the Paraná River. They reveal that the curimba (*P. Scrofa*), armado (*P. Granulosus*) and cascudo–preto (*R. Aspera*), species whose reproductive activity occurs in the stretch above Guaíra, develop migratory movements. Curimba were recaptured more than 400 km from the area they were set free, travelling at almost 9 km per day. Figure 11.9 illustrates the seasonal variations in these movements. There is a movement upward in the spring and summer, whereas the movement is mainly downward in fall and winter.

Based on data provided by tagging and spatial distribution per size and maturation stage, it has been seen that the species spawns in lotic parts upstream from the reservoir and the fish live in channels and marginal lagoons of the floodplain during their first two years. Upon reaching sexual maturity (2 years of age, 21.2 cm) they leave the floodplain and disperse throughout the basin until reaching the reservoir where they form a major part of the fishery.

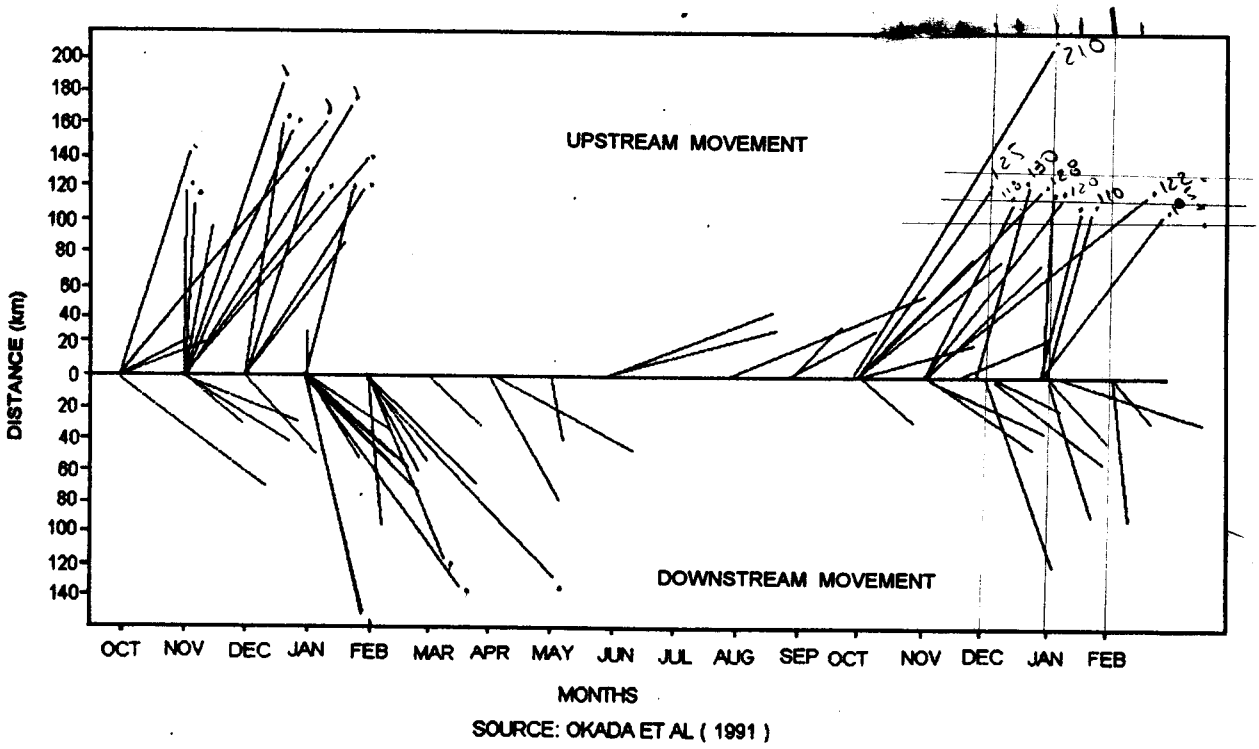
Seasonal movements associated with reproduction were also registered for the armado.[24] This species can reach speeds of nearly 27 km per day and swim more than 200 km. The upward migration occurs mainly from October to December and the downward movements from February to June (figure 11.10). That this species enters the reservoir early in life is demonstrated by the many fry in the branches of the reservoir, close to the lotic environment of the tributaries.

Cascudo–preto was observed to travel about 60 km away at daily speeds of close to 10.2 km. Unfortunately, it was not possible to provide details for this analysis due to the small sample of recaptured fish.

Table 11.10. Relative Abundance of H.edentatus and P.squamosissimuslarvac in the Itaipu Reservoir by Local

Local/Species	H.edentatus	P.squamosissimus
GUAÍRA	+	+
A.GUACU	+++	++
PTO.BRIT NIA	++++	++++
STA.HELENA	++++	++++
SÃO VICENTE	+++	+++
OCOI	++++	++++
FOZ IGUACU	+	+++

Figure 11.10. Movements of *P. Granulosus* in the Itaipu Reservoir and Paraná River



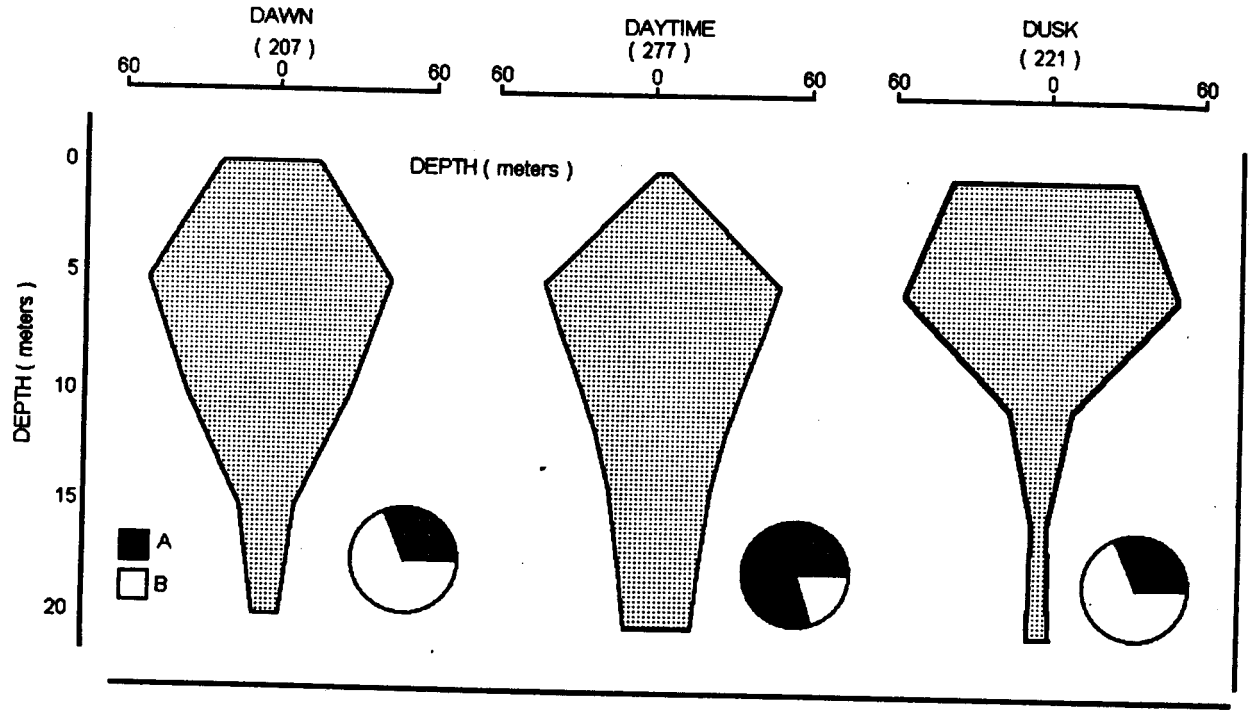
SOURCE: OKADA ET AL (1991)

Table 11.11. Equation Parameter of Selectivity Curve for Gillnets

Species	Equation of selectivity curve	Minimum mesh size recommended
P.scrofa	$C^*=\exp[-0.078(l-3.20m)]^2$	9
H.edentatus	$C^*=\exp[-0.068(L-4.94.m)]^2$	7
P.squamosissimus	$C^*=\exp[-0.067(L-3.71.m)]^2$	8

L=total length, m=mesh size, *=for adult catch

Figure 11.11. Vertical Migrations of *H. Edentatus*



SOURCE: BENEDITO - CECILIO (IN PRESS)

Since these migrations involve upstream movements for spawning, the tendency to restrict initial development to certain environments of the floodplain should be extended to protect other species within the Itaipu reservoir.

Lateral and Vertical Movements: The exploitation of mapará (*H. Edentatus*) in the Itaipu reservoir has been effected with gillnets whose meshes are unsuitable for catching other species. To reduce the adverse effects of this exploitation, research on spatial distribution (vertical and horizontal) of this species and its variation over 24 hours (figure 11.11) has been carried out.[25/] The species concentrate in the open areas (Point A) during the daytime and in marginal areas at night. In open areas this species is more abundant around 5 m depth. It is absent from the surface during the daytime, though it is plentiful there at dusk. It appears that the vertical and horizontal movements of the mapará are mainly associated with the search for food (zooplankton) rather than protection from predators.

Gillnet Selectivity: Table 11.11 provides an estimate of the gillnet selectivity curve parameters for catches of three commercial fish species. The table shows the minimum mesh sizes recommended for catching adults (the measurements quoted are in centimeters taken from knot to knot in the diagonal sense). Fishing of *R. Aspera* is mainly effected with casting nets and the *P. granulosus* fishery with gillnets and fishhooks.

An Evaluation of the Application of Biological Research and Management Techniques to Fishery Production in the Itaipu Reservoir

Fishery management in Brazilian reservoirs have been sporadic and usually lack adequate technical-scientific planning. The main application has involved the control over fisheries involving both native and exotic species. Fishery controls with inadequate basic biological information, monitoring programme and human and material resources have, as may be expected, been largely ineffective.

The stock option used to viably implant fisheries in reservoirs quickly have been unsatisfactory. For example, more than ten species were introduced to the Paraná River Basin. Most of these fish were not recaptured thereby leaving researchers with little information to work from. Stocking native fish is a new venture for Brazilian reservoir management. Alas, the lack of technology to gauge the progress of populations and the genetic impacts resulting from endo-and exo-crossing have thwarted a proper appraisal of this procedure.

Fortunately, some hydroelectric utilities have refocussed their efforts towards limnological and ichthyological research as a basis of fishery administration.

Limnologcial and ichthyological research in the Itaipu reservoir began in November of 1983. The monitoring of fishing started in 1985, while management measures were restricted to fishery control. Based on biological data regarding the fishery and socio-economic aspects, a set of fishing regulations was prepared to protect stocks and increase species diversity. Consequently, fisheries in tributaries were closed, thereby protecting the spawning grounds of species such as the curvina. Armado also spends its early life in tributaries.

Fishing for mapará is permissible using small mesh gillnets, however, they must be used in pelagic areas and in depths not exceeding 5 meters, which is where this species concentrates. Fishing in the reservior main body with gillnets of mesh sizes greater than 10 cm is allowed.

Itaipu Binacional has also developed ways to preserve the bathing beaches from piranha infestation (*Serrasalmus marginatus*), for the recovery of fishes entrapped in the turbine outlets during maintenance work on the power units, and techniques for breeding native species in net-tanks, thus providing alternative fish production systems.

The Itaipu reservoir fishery is greatly effected by what happens in the main tributaries of the Paraná River and its floodplain upstream. Therefore, an efficient management of fishery resources demands that protective measures be extended to the upper reaches of the basin. Thus, the protection or improvement of conditions in the spawning areas and natural nursery located in the first 200 km upstream from the Itaipu reservoir could help replenish this overall environment. It would be very beneficial for the reservoir fishery if upstream dams protected the minimum river flow requirements of fish species, especially during reproductive periods.

NOTES

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